DEVELOPMENT OF A TESTING PROCEDURE FOR PAINTS USED AS VAPOUR DIFFUSION RETARDERS

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EXECUTIVE SUMMARY

INTRODUCTION

Recent studies have indicated that polyethylene vapour diffusion retarders and polyethylene air/vapour barriers may deteriorate prematurely due to chemical degradation caused by the loss of the anti-oxidants and accelerated aging. In addition these polyethylene air/vapour barriers may not be able to withstand the air pressure imposed on them by wind or stack pressures within the building envelope.

A demonstration project of the Airtight Drywall Approach in 1984 indicated that the use of paints as a replacement for polyethylene vapour diffusion retarders found little support from the building inspection departments. This was largely due to the lack of appropriate technical information and standards.

This study addresses these issues by developing a testing method to determine the water vapour permeance of paints and primers applied to gypsum wallboard and providing a range of permeance values of common paints and primers used in the residential construction industry.

APPROACH

A literature review indicated that some paints and primers can adequately resist water vapour diffusion through building assemblies. Permeance values were less in a number of cases than the maximum of 60 ng/Pa•s•m^2 allowed under CAN2-51.33-M80.

A number of ASTM testing standards to determine water vapour permeance of paints were reviewed to assess their suitability as a testing method for paint vapour retarders in residential construction. None of these testing methods used gypsum board as a substrate and therefore the methods may not be representative for paints applied on gypsum board.

To more closely match the actual performance of paint vapour retarders applied to gypsum board a testing procedure was developed using gypsum board as a substrate. This testing procedure was then verified with respect to precision, reproducibility and ease of use. A range of common available paints and primers used in residential construction was tested to determine the water vapour permeance.

FINDINGS

The testing method to determine the water vapour permeance of paints applied to gypsum board was validated. This method provides precise and reproducible permeance values, is easy to use and is relatively inexpensive.

The water vapour permeance of common paints and primers was determined using the test method and the results are summarized as follows:

a) one coat of Alkyd Sealer has a permeance of 32 ng/Pa•s•m^2 which is well within the requirements of CAN2-51.33-M80;

b) one coat of Alkyd Sealer and one coat of Alkyd Low-Luster have a permeance of 28 ng/Pa•s•m^2;

c) one coat of Alkyd Sealer and one coat of Alkyd Semi-Gloss have a permeance of 38 ng/Pa•s•m^2;

d) one coat of Alkyd Sealer and one coat of Alkyd High-Gloss have a permeance of 34 ng/Pa•s•m^2;

e) one coat of Alkyd Sealer and two coats of Alkyd Low-Luster have a permeance of 13 to 14 ng/Pa•s•m^2;

f) two coats of Alkyd Sealer and two coats of Alkyd Low-Luster have a permeance of 11 to 13 ng/Pa•s•m^2;

g) a proprietary paint vapour retarder in combination with Latex Paint or Alkyd Enamel have a permeance of 11 to 46 ng/Pa•s•m^2;

h) one coat of Latex Sealer and one coat of Latex Paint have a permeance of 147 to 257 ng/Pa•s•m^2 which is well above the maximum permeance limits of CAN2-51.33-M80.

An experiment to study the effects of water vapour flow reversal indicated a moderate increase in water vapour diffusion and after 14 days no blistering or surface defects were observed.

Reducing the application rate of the sealer and paint to approximately 50% of the manufacturer's recommended rate still provided average permeance values within the requirements of CAN2-51.33-M80.

Increasing the application rate to well above the recommended manufacturer's rate did not produce a corresponding reduction in water vapour diffusion.

CONCLUSIONS

This study concludes that the developed testing procedure provides precise and reproducible results, is easy to use and relatively inexpensive.

Alkyd sealers and enamels are effective water vapour diffusion retarders but latex primers and paints cannot be considered adequate vapour diffusion retarders.

1.0 INTRODUCTION AND OBJECTIVES

1.1 Introduction

According to Lstiburek and Lischkoff, (1984), energy-efficient homes with low-energy losses due to air infiltration/exfiltration have been successfully built since 1977. In addition to reducing heating costs, the reduction or near elimination of this air movement is a major factor in reducing interstitial moisture problems in walls and condensation problems in roofs and attics. This is due to the fact that most of the moisture build up within wall cavities and attics is a result of the movement of moisture-laden air into the cavities as opposed to the diffusion of water vapour through the building envelope.

Polyethylene film used as an air barrier/vapour retarder brings with it problems such as high labour costs, chemical degradation, and lack of structural properties to resist wind loads. The installation of this film, in such a way to provide an integral air barrier/vapour retarder, involves a great deal of quality control and supervision by trained professionals (Lstiburek and Lischkoff, 1984). The high degree of airtightness of the building envelope that is required leads to higher costs in construction time and in training of staff. The polyethylene must also be protected during construction from being punctured or torn. A polyethylene air barrier/vapour retarder must be supported to resist wind and stack air pressures. The polyethylene will be sucked into a wall cavity under peak wind loading, rupture its seal and compress the insulation (Quirouette; 1983).

In addition to the above, polyethylene is susceptible to a chemical degradation process. This oxidation causes the polyethylene to become brittle and therefore much more vulnerable to fracture from normal wind and stack air pressures. The addition of improved anti-oxidants to polyethylene may become an accepted method of control for this oxidation process.

In response to these various problems, Handegord (1981) proposed the use of a painted surface as resistance to vapour diffusion.

Lstiburek and Lischkoff later developed a modified Handegord approach using plywood and/or waferboard strips in combination with painted gypsum wallboard. Later (1984) they went on to develop "Airtight Drywall Approach," also a non-polyethylene air barrier technique.

In the spring and summer of 1984, Alberta Municipal Affairs (then the Alberta Department of Housing) provided funding for the construction of three demonstration houses using the Airtight Drywall Approach (A.D.A.). This new approach utilized gaskets and gypsum wallboard to make houses airtight and used paint as an effective vapour retarder which eliminates the need for a polyethylene vapour-diffusion retarder. During the construction of the demonstration houses, it became clear that regulatory authorities did not accept paint on gypsum wallboard as a Class 2 vapour retarder, unless a professional engineer certified paints for use as a vapour retarder.

One approach to make paints acceptable as a vapour retarder is to determine the water permeance of various organic coatings in accordance with a nationwide accepted procedure.

1.2 Objectives

The objective of this study is to determine the feasibility of using paints on gypsum wallboard in residential construction as a water vapour retarder, thus eliminating the use of polyethylene vapour retarders. The main route to accomplish this goal is to develop a testing procedure and consensus standard that defines the testing procedure, the building materials and construction applications to allow the replacement of polyethylene by paint as an acceptable vapour retarder in building codes.

2.0 REVIEW OF LITERATURE AND STANDARDS

2.1 Review of Literature

The Canadian Standard CAN2-51.33-M80 "Vapour Barrier, Sheet, for use in Building Construction" sets a limit of 60 ng/Pa•s•m² (after aging) for the water vapour permeance of a Type 2 material (standard permeance). It is expected that any material that would be used to replace existing Type 2 vapour retarders be required to meet the same requirement of water vapour permeance.

Lstiburek and Lischkoff, (1984) reported the permeance values shown in Table 1, and stated that type 2 vapour retarder requirements can be met using paint films in the following manner:

a) one coat of semi-gloss latex paint over a single coat of a standard latex primer; or

b) three coats of flat latex over a single coat of a standard latex primer; or

c) one coat of flat latex over a single coat of "Insul-Aid" Primer, a proprietary material.

Hutcheon and Handegord, (1983) have reported permeance values for several different materials. The values for the applicable coating materials are shown here in Table 2.

Yaseen and Ashton, (1978) reported permeability measurements for various clear coatings. They have made correlations between permeability and durability, oil type and oil content. Yaseen and Ashton (1978) also state that "the permeability properties of coatings can be explained on the basis of the general characteristics of the materials used in the formulation and also their structural arrangement."

Table 1. Permeance Values - Literature

Paint Type	Permeance	Coverage (5 litres)
Semi-Gloss latex	33 ng/Pa•s•m²	42 m²
Flat latex	172 ng/Pa•s•m²	43 m²
Flat oil based	96 ng/Pa•s•m²	42 m²
Latex primer	350 ng/Pa•s•m²	23 m²
"Insul-Aid" primer	34 ng/Pa•s•m²	40 m²

Table 2. Water-Vapour Transmission Coefficients for Various Materials (from ASHRAE Handbook 1981 Fundamentals, Table 2, p. 21.6, 21.7).

Material	Permeance (ng/Pa·s·m²) dry cup	wet cup	other
Plaster on wood lath	-	630	
Plaster on plain gypsum lath on studs	-	-	1150
Gypsum wallboard, 9.5 mm, plain	-	-	2870
Hardboard, 3 mm, tempered	-	-	290
Plywood, douglas fir, exterior glue, 6.5 mm	-	-	40
Enamels, 2 coats on smooth plaster	-	-	29-86
Primers, sealers, 2 coats on insulation board	-	-	52-120
Various primers, 2 coats + 1 coat flat oil paint on plaster	-	-	92-172
Flat paint, 2 coats on insulation board	-	-	230
Water emulsion, 2 coats on insulation board	-	-	1720-4900
Exterior paint, 3 coats white lead in oil on wood siding	17-57	-	-
Styrene butadiene latex coating 0.62 kg/m²	630	-	-
Polyvinyl acetate latex coating 1.25 kg/m²	320	-	-

2.2 Review of Standards

ASTM D 1653 describes testing procedures for the determination of permeance values for unsupported organic coatings. These procedures are not applicable to the measurement of the permeance of thick materials, i.e. gypsum wallboard. There is also no certainty that permeance values obtained by this method represent values of a paint applied to a substrate.

The Canadian standard CAN2-51.33-M80 (Vapour Barrier, Sheet for Use in Building Construction) to determine the water vapour permeability for a Type 2 vapour barrier requires the use of testing method ASTM E 96. Procedure A of ASTM E 96 is for the use of the dry-cup (desiccant) method. The relative-humidity conditions specified in this procedure are 0% R.H. (or the vapour pressure of water above the desiccant) on the non-paint side of the gypsum board and 50% R.H. on the paint side of the gypsum board (outside the container). A relative humidity of 0% is obtained inside the pan by placing an appropriate desiccant here whereas 50% R.H. outside the pan is obtained by placing the assembly into a controlled environment room.

Although the wet-cup method indicates if there is any drastic change in permeability with an increase in R.H., the dry cup more nearly approaches the conditions of use. Here, in a heating climate, a higher humidity (but not extreme) is obtained on the paint side of a wall (inside a house) and is being transmitted to the outside where a cold/low humidity environment exists. (See also ASTM C 755 "Standard Practice for Selection of Vapour Retarders for Thermal Insulation" for some relevant definitions).

The testing procedure outlined in ASTM E 96 requires samples of 254 mm by 254 mm. The actual exposure area of the sample should depend upon the specific permeability of the material but an area of 254 mm by 254 mm is appropriate. [A calculation of the mass of water permeating a material of this size, with a maximum allowable permeance of 60 ng/Pa•s•m^2 (see CAN2-51.33-M80), a vapour pressure difference $P_1 - P_2 = 1405$ Pa (50% R.H. difference) over a 30-day period indicates that approximately 14g of water will be transmitted. According to ASTM specifications, the amount of desiccant used per test must be such that the increase in weight over the test period does not exceed 10% of the desiccant's weight]. Therefore, the design of an appropriate dish should take into consideration that it must contain at least 140 g of desiccant and a size of 254 mm by 254 mm can accommodate this with ease.

2.3 Conclusions

Studies indicate that several types of organic coatings such as latex and oil based paints can decrease the transmission of water vapour to, in some cases, a high degree. Although the permeance values appear acceptable in some cases, these values were obtained using free films, and therefore the effect of the interaction between paint coatings and gypsum wall board is not known. Therefore a more appropriate testing method, taking into consideration the combination of materials as an assembly, may provide more accurate values for the water vapour permeability.

3.0 TESTING PROCEDURE

3.1 Introduction

The development of a procedure to determine the water vapour permeance of various coatings applied to gypsum wallboard must take into consideration several different testing methods. Among these are standard methods for the determination of permeance of thick materials, organic films and sheet material.

The substrate of each sample is the gypsum wallboard. Therefore any applicable method must accommodate this type of thick material (see Section 2.2 for a rationale of sample size and general procedure). The sample is also composed of one or several layers of paint. Methods will be discussed and chosen in order to provide a uniform thickness of paint along with consistent application.

The method must also provide accuracy within the limits of allowable permeance values (see CAN2-51.33-M80) by means of simple apparatus and reasonable cost.

3.2 Selection of Materials

3.2.1 Selection of Substrate

The substrate used in these tests was gypsum wallboard having a thickness of 12.7 mm. This material is the one that is the most widely used in residential and commercial construction and by testing the combination of paint and gypsum wallboard, the results will more closely resemble actual installed performance.

3.2.2 Selection of Desiccant

The purpose of the desiccant, as outlined in Section 2.2, is to provide an atmosphere as near as possible to 0% R.H. on one side of the test sample. Therefore, if a 0% R.H. is established on one side of the sample and the other is exposed to a 50% R.H., a driving force is created whereby the water vapour flows from the high vapour pressure side to the low. The mass increase of the desiccant is measured and the amount of water passing through the sample is determined. The assessment criteria for a desiccant under the present conditions are that of having a high affinity for water and a high drying efficiency, i.e., giving a low water vapour pressure after absorbing a large amount of water.

The following materials were considered for use in this procedure as desiccants:

a) phosphorus pentoxide - extremely efficient, rapid but expensive, and produces phosphoric acid which could exert

a chemical action upon the testing material;

b) calcium chloride - high drying capacity, inexpensive, not rapid;

c) calcium sulfate - fast, efficient but only 6.6% of its weight in water can be absorbed to retain its maximum efficiency;

d) magnesium sulfate - rapid acting, neutral, inexpensive but only fairly efficient; and

e) sodium sulfate - slow and inefficient.

The preferred desiccant is calcium chloride because of its high drying capacity and also because it can be easily regenerated to a condition of known moisture content.

3.2.3 Selection of Paints

The organic coating materials were chosen to scan a wide range of material types. The purpose was not to perform an exhaustive comparison of materials but to outline an appropriate method which could do this.

The choice of paints was made according to accepted indoor use and was also made to cover a wide range of permeance values. These materials are latex paint (Low-Luster), alkyd enamel (Low-Luster, Semi-Gloss and High-Gloss) and a special vapour retarding paint.

3.2.4 Selection and Importance of Primer

The selection of an appropriate primer was made in consultation with the paint industry and according to the paint coating to be used.

The importance of the water vapour permeability of the primer coat may be of significance especially in regards to ceiling finishes. A common technique involves the finishing of ceilings with stipple. Diehl, (1960) defines stippled finish as the additional plaster daubed over the surface with a stippling brush. According to this manual, variations of texture can be obtained by using different application methods. Builders in Edmonton commonly apply a suspension of cement and plaster in water to a surface coated with a water-based (or water-borne) latex primer or a flat white latex paint. For this reason then, the primer coat applied under stipple should be a water vapour retarding coating. If the ceiling finish is an integral part of the vapour retarder system, e.g. in a one-storey house or in upper storey of a two-storey house, then appropriate retarder materials should be used under the stipple.

3.3 Selection of Methods

3.3.1 Paint Application Method

The procedures outlined for preparing and testing unsupported paint films (ASTM D 1653 and D 1005) assign criteria for precision and allowable variation in thickness of these films. Therefore an acceptable method of application of paint layers on gypsum wallboard must be one that produces a uniform layer.

General methods of paint application are by spraying, by roller or by brush, of which the first two are generally accepted in the paint industry as able to produce the most consistent application rates.

The purpose of spray painting is to create minute particles that hit a surface and flow into a continuous film. Spraying is generally carried out with two different systems: air pressure spray and hydraulic (airless) spray. Airless sprays appear to have advantages over air pressure spray because they can be sprayed at container consistency. Both types of spray guns give a fan spray pattern. The angle of the fan, the tips of the guns and rate of flow must be adjusted according to the type of paint and the surface the paint is applied to. In order to achieve the best results, both manufacturer's air sprayer and coating recommendations must be followed.

Roller application is the most general method of paint application accepted by the paint industry. This method produces a consistent layer, is easy to use and inexpensive and was therefore chosen.

3.3.2 Paint Film Thickness Measurement

In order to measure the film thickness, strips of polyethylene or aluminum foil were attached to appropriate locations of the drywall before paint application. The thickness of these is then measured upon subsequent paint applications. The measurement of the paint thickness on plastic or foil strips as a monitor of paint film thickness was abandoned in favour of simple weight monitoring of the amount of paint applied to a known gypsum wallboard.

3.4 Experimental Testing Procedure

3.4.1 Sample Preparation

The coating to be tested on gypsum wallboard was applied using a standard 254 mm roller as recommended by the manufacturers. Before applying the coating(s) to the gypsum wallboard, the painting tray, the roller, and the coating material in the container to be tested were weighed together. The coating

material was then applied by roller over the surface of a 610 mm by 1220 mm piece of gypsum wall board in one direction until the surface was covered and then in the other direction. This procedure was repeated until the surface was covered by the amount of coating recommended by the manufacturer.

Care was used to ensure a consistent, even coating and to minimize any loss of coating material.

The assembly consisting of painting tray, leftover coating material and the roller was weighed after the painting was completed. The difference in mass between this and the first weighing was considered to be the quantity of paint applied to the gypsum board. The above procedure was repeated for each coating applied to the gypsum wallboard. Pieces of board 279 mm by 279 mm were then cut from areas at least 50 mm away from the edges of the gypsum board.

3.4.2 Sample Assembly and Weighing

The coated gypsum wallboards to be tested were seated on an aluminum tray having the shape and the dimensions as indicated in ASTM Standard E 96. The bottom of the tray was covered with a plastic film (polyethylene) in order to protect the tray from the corrosive effects of the desiccant. A 250 g amount was weighed into the tray, and before seating the board on the tray, the desiccant was spread evenly on the bottom of the tray.

The desiccant used was commercial-grade anhydrous calcium chloride ($CaCl_2$, 94 to 97%, Harrisons & Crosfield [Canada] Ltd.) in bead form, up to 1 mm in diameter and was used as received.

The board seated on the aluminum tray was then sealed with paraffin wax in order to permit the flux of water vapour only through a 254 mm by 254 mm area. Molten paraffin wax was applied with the help of a brush on the inner edges of the pan; the board was set on the ledges and the wax was pressed gently into place. An aluminum template was centered on the surface of the board and wax was poured into the space surrounded by the sides of the tray and the edges of the template. The sides of the assembly were cleaned of excess wax by scraping with a spatula and buffing with a cloth. Care was also taken so that the surface to be tested did not have small particles of wax on it.

The sample assembly (gypsum board with coatings, desiccant, pan and wax) was then weighed before it was transferred into an "ambient room" with a constant temperature of 23 ± 0.6°C and relative humidity of 50 ± 2%. The samples were kept in the ambient room for the duration of the experiment.

Each sample assembly was weighed to the nearest one-hundredth gram at approximately 24-hour intervals and the time of weighing was recorded. Records on relative humidity and temperature were also kept for calculating the moisture accumulation.

3.4.3 Calculations

The calculation for the % coverage of each paint layer was done as follows:

$$\% \text{ Coverage} = \frac{\text{Amount of Paint Used}}{\text{Amount of Paint Recommended}} \times 100$$

The permeance values were calculated from at least four or more points falling on a straight line in the Δm vs time graph.

A second method of calculating the permeance would involve using the change in mass and the time span for the duration of the experiment. (Some values for comparison are shown in Table 3.) The first method of calculation was chosen because in the first part of the experiment the mass may change rapidly. Later, a steady state will be reached where the rate of change is essentially constant.

The permeance values were calculated as follows:

$$\text{Permeance } (ng/Pa \cdot s \cdot m^2) = \frac{C \times \Delta m}{RH \times h}$$

where Δm = the difference in mass (g) between the first and the last point falling on the same straight line of at least four or more points,

RH = percent relative humidity divided by 100,

h = time in hours elapsed between the two weighings determining Δm,

C = a constant derived from the following term:

$$= \frac{10^9 \text{ grams}}{2809 \text{ Pa} \times 3600 \text{ s} \times 0.064516 \text{ m}^2}$$

4.0 TESTING PROGRAM

4.1 Introduction

The scope of the testing included a practical evaluation of the testing procedure, in order to modify it as required to assure reliable permeance values. In addition the dependence of the variation of the water vapour transmission (of the selected procedure) on a number of variables was determined and their effect on the ease of testing examined.

The testing program described here was composed of the following studies:

a) A Preliminary Validation of Testing Method;
b) Material Test Scan;
c) Reproducibility Test;
d) Vapour Flow Reversal;
e) Application Rate Test;
f) Commercial Application Tests; and
g) Method, Application and Operation Tests.

4.2 Preliminary Validation of Testing Method

4.2.1 Description of Test

The testing program began with a series of experiments to determine any major problem areas. The results from this series of experiments indicated the appropriate desiccant level to be added in order to prevent saturation. In addition this test set identified any handling difficulties such as board warping, sealing and weighing problems.

4.2.2 Test Results

This series of tests included the samples listed in Table 3. Sample numbers 4, 8, 12, and 16 were the controls for the previous three sample numbers. These (controls) consisted of prepared samples where the desiccant was not included in the tray. The mass of these control samples remained essentially constant throughout the duration of the experiment which in this case was 16 to 28 days. Controls were not included in any subsequent tests.

The measurement of the paint thickness on plastic or foil strips as a monitor of paint film thickness was abandoned in favour of simple weight monitoring of the amount of paint applied to a known gypsum wallboard.

The permeance values listed in Table 3 were calculated by the following methods:

a) The first one (1) was calculated for the complete duration of the experiment.

b) A second value (2) was calculated using four consecutive points that showed a linear increase in mass.

Although only approximately 75% of the recommended coverage was obtained in this first series of tests (#5-16), the permeance values showed a marked decrease upon application of a single layer of latex sealer (#5-7). A further smaller decrease was observed with subsequent application of one (#9-11) and then two layers of latex paint (#13-16).

This first test series indicated that the method worked well, with no major handling or procedural difficulties encountered, and there were no failures due to air leaks.

The initial permeance values of latex paints did not appear promising as vapour retarders, and therefore the general emphasis was directed towards the investigation of better water vapour retarding paints.

Table 3 Permeance Values and Percent Coverages for Preliminary Validation of Testing Method (See Note - "Reading Table")

Sample #	Paint Coverage (%) GWB	1ES	1EP*	2EP	Permeance (1) ng/Pa•s•m^2	Permeance (2) ng/Pa•s•m^2
1	Y				891	865
2	Y				792	813
3	Y				849	863
4	Control Sample				N/A	N/A
5	Y	- 75			288	276
6	Y	- 75			392	381
7	Y	- 75			385	363
8	Control Sample				N/A	N/A
9	Y	- 75	- 75		247	254
10	Y	- 75	- 75		243	235
11	Y	- 75	- 75		248	229
12	Control Sample				N/A	N/A
13	Y	- 75	- 75	- 75	209	195
14	Y	- 75	- 75	- 75	212	190
15	Y	- 75	- 75	- 75	210	196
16	Control Sample				N/A	N/A

GWB - Gypsum Wallboard - Y - yes
ES - Latex Sealer
EP - Latex Paint
(1) - Calculation Method One (see text) p. 13
(2) - Calculation Method Two (see text) p. 13
* - Low-Luster Paint Used
N/A - Not Applicable
Note - "Reading Table" - Example 14 is read from left to right as composed of 1 GWB - gypsum wallboard with 1 coat of ES at 75% coverage then 1 coat of EP at 75% coverage followed by another coat of EP at 75% coverage with permeance values of 212 (1) and 190 (2)

4.3 Material Test Scan

4.3.1 Description of Test

The second set of experiments was used to determine the water vapour diffusion characteristics of commonly available paints and primers. Various combinations of latex paint, latex sealer, alkyd sealer, alkyd enamel and special vapour retarding paint were surveyed for permeance values.

4.3.2 Test Results

Tables 4 and 5 give individual permeance values and coverages for the test samples.

A summary of the results is presented in Table 6. The test results obtained indicate that the alkyd sealer, alkyd paint and the vapour retarder paint are superior to the latex coatings in effectiveness as water vapour retarder coatings (compare Table 3, see p. 14).

The time required to monitor the weight increase of the samples (up to a maximum of 10% of the $CaCl_2$ mass) will vary depending on the permeance value. Approximately 12 days was sufficient for this series of tests.

Table 4 Permeance Values and Percent Coverages for Material Test Scan - Latex and Alkyd Paints

SAMPLE #	Paint Coverage (%) 1 ES	2 ES	1 AE	2 AE	1 EP	2 EP	1 AS	2 AS	Permeance ng/Pa•s•m^2
17			107.7					101.1	16
18			107.7					101.1	16
19				104.5				101.1	11
20				104.5				101.1	13
21			172.8				110.9		18
22			172.8				110.9		18
23				136.2			110.9		14
24				136.2			110.9		13
25		100.0			97.0				221
26		100.0			97.0				197
27		100.0				91.2			147
28		100.0				91.2			171
29					77.9		119.7		38
30					77.9		119.7		32
31						69.4	119.7		30
32						69.4	119.7		25
33	103.8				113.0				254
34	103.8				113.0				225
35	103.8					95.7			241
36	103.8					95.7			195
37	124.2		105.0						49
38	124.2		105.0						52
39	124.2			115.2					37
40	124.2			115.2					30

ES - Latex Sealer
AE - Alkyd Enamel
EP - Latex Paint
AS - Alkyd Sealer

Table 5 Permeance Values and Percent Coverages for Material Test Scan - Latex, Alkyd and Vapour Retarder Paint

SAMPLE #	Paint Coverage (%) 1 VB	2 VB	1 AE	2 AE	1 EP	2 EP	Permeance ng/Pa•s•m^2
41	144.2				70.7		33
42	144.2				70.7		46
43	144.2					78.7	43
44	144.2					78.7	40
45	144.2			83.0			11
46	144.2			83.0			12
47	144.2		82.7				16
48	144.2		82.7				26
49		148.9			82.3		18
50		148.9			82.3		34
51		148.9				76.4	20
52		148.9				76.4	28
53		148.9		159.3			17
54		148.9		159.3			25
55		148.9			147.8		23
56		148.9			147.8		26

VB - Vapour Retarder Paint
EP - Latex Paint
AE - Alkyd Enamel

Table 6 Permeance Values - Summary - Material Test Scan

Coatings	Permeance (ng/Pa•s•m^2)
Latex Sealer/Latex Paint	147 - 257
Latex Sealer/Alkyd Paint	30 - 52
Alkyd Sealer/Latex Paint	25 - 38
Alkyd Sealer/Alkyd Enamel	11 - 18
Vapour Retarder Paint/Latex Paint	18 - 46
Vapour Retarder Paint/Alkyd Enamel	11 - 25

4.4 Reproducibility of Test Method

4.4.1 Description of Test

The third set of tests was undertaken to determine the reproducibility of the testing method by using a large number of replicates for each sample. The two samples examined were chosen to indicate the reproducibility at both ends of the scale (i.e. one high permeance and one low). Another objective of this series was to give an indication of the number of replicates required to give representative results.

4.4.2 Test Results

The results for the reproducibility tests are shown in Tables 7 and 8 for the latex and alkyd paints respectively. The statistical evaluation including values for the mean, standard deviation and 95% confidence limit is also included in each table.

These 10 replicates of each sample indicate very acceptable standard deviations, of 11.6 (mean = 286) for the latex samples and 2.8 (mean = 21) for the alkyd.

From these results the procedural errors of the method are more significant for the lower permeance coatings than the high-permeance coatings as a percentage of the determined value.

In agreement with the ASTM E 96, three test specimens should be used to determine the permeance of a coated gypsum wallboard.

Table 7 Reproducibility - Latex Paint
Latex Sealer/Latex Paint

Sample Number	Permeance (ng/Pa•s•m^2)	% Coverage	
		Sealer	Paint
61	293	102.7	119.8
62	283	102.7	119.8
63	294	102.7	119.8
64	281	102.7	119.8
65	284	102.7	119.8
66	295	102.7	119.8
67	276	102.7	119.8
68	271	102.7	119.8
69	258	102.7	119.8
70	288	102.7	119.8

Mean = 282 Std. Dev. = ±11.6 95% Conf. Limit = ±6.7

Table 8 Reproducibility - Alkyd Paint
Alkyd Sealer/Alkyd Enamel

Sample Number	Permeance (ng/Pa•s•m^2)	% Coverage	
	Sealer	Paint	
71	21	121.5	166.1
72	19	121.5	166.1
73	14	121.5	166.1
74	20	121.5	166.1
75	23	121.5	166.1
76	19	121.5	166.1
77	23	121.5	166.1
78	21	121.5	166.1
79	23	121.5	166.1
80	23	121.5	166.1

Mean = 21 Std. Dev. = ±2.8 95% Conf. Limit = ±1.6

4.5 Vapour Flow Reversal

4.5.1 Description of Test

The fourth set of tests was performed to determine the characteristics under vapour flow reversal conditions. The painted side of the gypsum wallboard was placed inwards toward the desiccant. The painted surface was examined upon test completion for evidence of blistering.

4.5.2 Test Results

The results of these tests shown in Tables 9 and 10 indicate that the permeance values increased slightly over those obtained in normal testing. (Compare Table 8 for alkyd paints.) The difference in coverages makes this comparison tenuous. Both the alkyd paint and a special vapour retarder paint did not show any blistering or surface defects upon removal from the pans.

Table 9 Vapour Flow Reversal - Alkyd Paint
Alkyd Sealer/Alkyd Enamel

Sample Number	Permeance (ng/Pa•s•m^2)	% Coverage	
		Sealer	Paint
81	40	98.7	97.4
82	44	98.7	97.4
83	32	98.7	97.4
84	41	98.7	97.4
85	74	98.7	97.4

Table 10 Vapour Flow Reversal - Vapour Retarder Paint

Sample Number	Permeance (ng/Pa•s•m^2)	% Coverage
86	38	146.6
87	24	146.6
88	57	146.6

4.6 Application Rate Tests

4.6.1 Description of Test

The fifth set of tests was designed to study the permeance variation when only 50% of the recommended coverage was used.

4.6.2 Test Results

The sensitivity to application rate was investigated for the alkyd sealer and enamel. The results are shown in Tables 11 and 12. The results indicate that there is approximately a twofold increase in the permeance value at 50% coverage in the case of the alkyd sealer plus alkyd enamel (Compare sample #21 and #22 as well as #95-104).

The alkyd base sealer at 50% coverage (Permeance = 43-100 ng/Pa•s•m^2) may also be compared to the commercial application rate (Table 13, permeance = 32 ng/Pa•s•m^2).

Table 11 Application Rate Test - Alkyd Sealer

Sample Number	Permeance (ng/Pa•s•m^2)	% Coverage
89	43	50
90	46	50
91	100	50

* Even application of paint at 50% of recommended coverage was difficult; uneven application of the sealer could be the cause for the large variation in permeance values.

Table 12 Application Rate Test - Alkyd Sealer/Alkyd Enamel

Sample Number	Permeance (ng/Pa•s•m^2)	% Coverage	
		Sealer	Enamel
92	43	50	47.9
93	41	50	47.9
94	38	50	47.9

4.7 Commercial Application Test

4.7.1 Description of Test

The sixth series of tests monitored the effects of having the paint coatings applied by a commercial painter. Ten sheets of gypsum wallboard were mounted vertically to simulate an actual wall. The boards were then primed (10 boards), sanded, and 5 of the 10 were painted. The method of application was by roller and the coating was an alkyd base. Several samples were then taken at random for testing.

4.7.2 Test Results

The results shown in Tables 13 and 14 demonstrate the reproducibility of the permeance values under standard residential application. The values obtained (i.e. 32 for the alkyd base sealer and 27 for the combination of alkyd sealer and enamel) are similar to those found previously for alkyd paint (see Table 9 p. 20, permeance = 32-74 ng/Pa•s•m^2).

These values are still well within the criteria outlined by the CGSB standard CAN2-51.33-M80 of 60 ng/Pa•s•m^2 as an acceptable water vapour retarder.

Table 13 Commercial Application - Alkyd Sealer

Sample Number	Permeance (ng/Pa•s•m^2)	% Coverage
105	34	93.7
106	42	93.7
107	35	93.7
108	34	93.7
109	31	93.7
110	30	93.7
111	28	93.7
112	27	93.7
113	34	93.7
114	30	93.7

Mean = 32 Std. Dev. = ±4.3 95% Conf. Limit = ±2.5

Table 14 Commercial Application - Alkyd Sealer/Alkyd Enamel

Sample Number	Permeance (ng/Pa•s•m^2)	% Coverage	
		Sealer	Enamel
95	35	130.0	132.3
96	23	130.0	132.3
97	29	130.0	132.3
98	20	130.0	132.3
99	28	130.0	132.3
100	17	130.0	132.3
101	34	130.0	132.3
102	24	130.0	132.3
103	28	130.0	132.3
104	32	130.0	132.3

Mean = 27 S.D. = ±5.9 95% Conf. Limit = ±3.4

4.8 Method, Application and Operation Tests

4.8.1 Description of Test

The seventh series of tests had two objectives. The first objective was to ascertain procedural or technical variations by having a different laboratory technologist apply the coatings to the gypsum wallboard (under controlled laboratory conditions as in experimental sets one to five). The second objective was to determine permeance values for Semi-Gloss and High-Gloss paints for comparison to the Low-Luster paint.

4.8.2 Test Results

The results of the seventh series of tests are shown in Tables 15, 16 and 17. Three different operators have now been used to apply coatings in various tests. These results indicate good reproducibility of water vapour permeance values when different operators apply the paint to gypsum wallboard. The measured permeance value for the Low-Luster alkyd enamel is 28 ng/Pa•s•m^2 as compared 27 and 21 ng/Pa•s•m^2 for the Commercial Application Test (Table 14) and the Reproducibility Test (Table 8) respectively.

These results also indicate that the measured permeance values for the Low-Luster, Semi-Gloss and High-Gloss alkyd enamel are 28, 38 and 34 ng/Pa•s•m^2 respectively. Although no definite conclusion can be drawn from these results due to the differences in % coverages, there does not appear to be any correlation between the type of paint finish and the permeance. All three still fall within the accepted limit of 60 ng/Pa•s•m^2.

Table 15 Method, Application and Operation Test
Alkyd Sealer/Alkyd Enamel
(Low-Luster)

Sample Number	Permeance (ng/Pa•s•m^2)	% Coverage	
		Sealer	Enamel
115	22	89.6	78.4
116	24	89.6	78.4
117	26	89.6	78.4
118	22	89.6	78.4
119	31	89.6	78.4
120	23	89.6	78.4
121	33	89.6	78.4
122	28	89.6	78.4
123	35	89.6	78.4
124	37	89.6	78.4

Mean = 28 Std. Dev. = ±5.6 95% Conf. Limit = ±3.2

Table 16 Method, Application and Operation Test
Alkyd Sealer/Alkyd Enamel
(High-Gloss)

Sample Number	Permeance (ng/Pa•s•m^2)	% Coverage	
		Sealer	Enamel
125	34	94.3	77.5
126	35	94.3	77.5
127	37	94.3	77.5
128	33	94.3	77.5
129	30	94.3	77.5

Mean = 34 Std. Dev. = ±2.6 95% Conf. Limit = ±2.5

Table 17 Method, Application and Operation Test
Alkyd Sealer/Alkyd Enamel
(Semi-Gloss)

Sample Number	Permeance (ng/Pa•s•m^2)	% Coverage	
		Sealer	Enamel
130	36	94.3	101.5
131	35	94.3	101.5
132	39	94.3	101.5
133	31	94.3	101.5
134	51	94.3	101.5

Mean = 38 Std. Dev. = ±7.6 95% Conf. Limit = ±7.2

4.9 Summary of Test Results

The water vapour permeance test method detailed here can be done with relatively inexpensive materials and is easy to perform. Meaningful results were produced in 10 to 15 days.

The evaluation of the experimental testing method indicated precise and reproducible permeance values. (Compare Tables 8, 14 and 15.)

The results of the study are summarized in Table 18. These results show permeance values of 147-280 ng/Pa•s•m2 for the latex coatings tested. These values are within the literature values shown in Tables 1 (p. 3) and 2 (p. 4) but are greater than the required permeance values set in CAN2-50.33-M80. These values represent permeance values for the latex paint applied to gypsum wallboard whereas those in Tables 1 and 2 are based on the testing of paint films.

The permeance values obtained for the alkyd and special vapour retarder paint, (11-46 ng/Pa•s•m2) are below the required water vapour permeance for an accepted vapour retarder coating, (60 ng/Pa•s•m^2 according to CAN2-51-33-M80).

The application rate test results indicate that the permeance values increase substantially as the percentage coverage is decreased from 100% of the manufacturer's recommended coverage to 50%. There does not appear to be such a correlation when the coverage is increased beyond 100%. (Compare Tables 4, 14, and 15.)

The vapour flow reversal study showed only a minor increase in the permeance values and the coatings did not show any blistering or cracking.

Table 18 Summary of Results of Permeance Values for Various Paints Tested

Material	Permeance ng/Pa•s•m^2	Literature Values (from Table 1)
Latex Sealer/Latex Paint	147-286	33-350
Vapour Retarder Paint/Latex Paint	18-46	34
Vapour Retarder Paint/Alkyd Enamel	11-25	34
Alkyd Sealer/Alkyd Low-Luster Enamel (Test Scan)	11-18	-
Alkyd Sealer/Alkyd Low-Luster Enamel (Reproducibility Test)	21	-
Alkyd Sealer/Alkyd Low-Luster Enamel (Commercial Application)	27	-
Alkyd Sealer/Alkyd Low-Luster Enamel (Operation Test)	28	-
Alkyd Sealer/Alkyd Semi-Gloss Enamel (Operation Test)	38	-
Alkyd Sealer/Alkyd High-Gloss Enamel (Operation Test)	34	-

5.0 FINDINGS AND CONCLUSION

The testing method to determine the water vapour permeance of paints applied to gypsum board was validated. This method provides precise and reproducible permeance values, is easy to use and is relatively inexpensive.

The water vapour permeance of common paints and primers was determined using the testing method and the results are summarized as follows:

a) one coat of Alkyd Sealer has a permeance of 32 ng/Pa•s•m^2 which is well within the requirements of CAN2-51.33-M80;

b) one coat of Alkyd Sealer and one coat of Alkyd Low-Luster have a permeance of 28 ng/Pa•s•m^2;

c) one coat of Alkyd Sealer and one coat of Alkyd Semi-Gloss have a permeance of 38 ng/Pa•s•m^2;

d) one coat of Alkyd Sealer and one coat of Alkyd High-Gloss have a permeance of 34 ng/Pa•s•m^2;

e) one coat of Alkyd Sealer and two coats of Alkyd Low-Luster have a permeance of 13 to 14 ng/Pa•s•m^2;

f) two coats of Alkyd Sealer and two coats of Alkyd Low-Luster have a permeance of 11 to 13 ng/Pa•s•m^2;

g) a proprietary paint vapour retarder in combination with Latex Paint or Alkyd Enamel have a permeance of 11 to 46 ng/Pa•s•m^2;

h) one coat of Latex Sealer and one coat of Latex Paint have a permeance of 147 to 257 ng/Pa•s•m^2 which is well above the maximum permeance limits of CAN2-51.33-M80.

An experiment to study the effects of water vapour flow reversal indicated a moderate increase in water vapour diffusion and after 14 days no blistering or surface defects were observed.

Reducing the application rate of the sealer and paint to approximately 50% of the manufacturer's recommended rate still provided average permeance values within the requirements of CAN2-51.33-M80.

Increasing the application rate to well above the recommended manufacturer's rate did not produce a corresponding reduction in water vapour diffusion.

This study concludes that the developed testing procedure provides precise and reproducible results, is easy to use and relatively inexpensive.

Alkyd sealers and enamels are effective water vapour diffusion retarders but latex primers and paints cannot be considered adequate vapour diffusion retarders.

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APPENDIX A

PROPOSED TESTING STANDARD

APPENDIX A

1.0 SCOPE

1.1 This standard covers the performance requirements of commercial paints applied to standard (12.7 mm) gypsum wallboard material for use in controlling water vapour diffusion through horizontal and vertical building assemblies.

1.2 The material involved in this standard is intended for use in above-grade building construction (or below-grade building construction).

2.0 APPLICABLE PUBLICATIONS

2.1 The following publications are applicable to this standard:

2.1.1 Canadian General Standards Board (CGSB)

CAN2-51.33-M80	Vapour Barrier, Sheet, for use in Building Construction

American Society for Testing and Materials (ASTM)

C 755	Standard Practice for Selection of Vapour Retarders for Thermal Insulation
D 823	Producing Films of Uniform Thickness of Paint, Varnish, Lacquer and Related Products on Test Pan
D 1005	Measurement of Dry Film Thickness of Organic Coatings using Micrometers
D 1653	Moisture Vapour Permeability of Organic Coating Films
E 96	Standard Test Methods for Water Vapour Transmission of Materials

2.2 Reference to the above publications is to the latest issues, unless otherwise specified by the authority applying this standard.

3.0 TERMINOLOGY

3.1 Vapour Retarder - A material that retards the transmission of water vapour under specified conditions.

3.2 Detail Requirement

When applied to gypsum wallboard in accordance with the manufacturer's instructions and tested with the dry-cup procedure the system shall have a water vapour permeance not exceeding 60 ng/Pa•s•m^2.

3.3 Preparation for Delivery

3.3.1 Packing, Packaging and Marking

Normal commercial methods of packing, packaging and marking shall be acceptable.

3.3.2 Labelling

Each container of material shall be identified by a clearly visible label. The label shall identify the contents as vapour retarding material conforming to this standard in a manner similar to the following:

(Trade name)
Paint Vapour Retarder
Complies with CGSB Standard CAN ...

The label shall include the manufacturer's name, address and trademark and shall include the manufacturer's recommended coverage so as to meet this standard.

3.4 Materials

3.4.1 Sampling

Each sample shall consist of a 4L container of paint.

3.4.2 Material

The coating materials shall be applied to standard 12.7 mm (1/2") gypsum board consisting of one coat of primer and two coats of finish unless otherwise specified in the manufacturer's instructions.

3.4.3 Application Method

In order to obtain a uniform film of consistent thickness the material shall be applied in accordance with ASTM D 1005.

3.5 TESTING METHOD

3.5.1 Conditioning

Unless otherwise recommended in the manufacturer's specifications, the painted gypsum board sections shall be conditioned to constant weight (±x%: tolerance depends upon size of specimens) at 23±2° C and 50±5% R.H.

3.5.2 Water Vapour Permeance

3.5.2.1

Determine the water vapour permeance on three specimens in accordance with ASTM E 96 (Desiccant Method).

3.6 USES (NOTES)

3.6.1

Selection of the vapour retarder material for any given situation should depend on the specific environment where the material will function. For further information, refer to ASTM C 755.

3.6.2

The materials described herein are intended primarily for use in conventional dwelling construction in which high wintertime relative-humidity conditions are not anticipated.

3.6.3

To attain a vapour retarder in the building envelope using material to this standard, care should be taken during construction to apply methods that prevent air leakage. The coating is of minor importance compared to sealing openings in the construction.

APPENDIX B

EXISTING STANDARDS

APPENDIX B

EXISTING STANDARDS

ASTM C 36	Standard Specification for Gypsum Wallboard.
ASTM C 473	Standard Methods for Physical Testing of Gypsum Board Products, Gypsum Lath, Gypsum Partition Tile or Block and Precast Reinforced Gypsum Slabs.
ASTM C 755	Standard Practice for Selection of Vapour Retarders for Thermal Insulation.
ASTM D 823	Producing Films of Uniform Thickness of Paint, Varnish, Lacquer and Related Products on Test Pan.
ASTM D 1005	Measurement of Dry Film Thickness of Organic Coatings using Micrometers.
ASTM D 1653	Moisture Vapour Permeability of Organic Coating Films.
ASTM E 96	Standard Test Methods for Water Vapour Transmission of Materials.
CGSB CAN2-51.33-M80	Vapour Barrier, Sheet, for Use in Building Construction.

APPENDIX C

PHOTOGRAPHIC DESCRIPTION

OF

EXPERIMENTAL METHOD

LIST OF PHOTOGRAPHS

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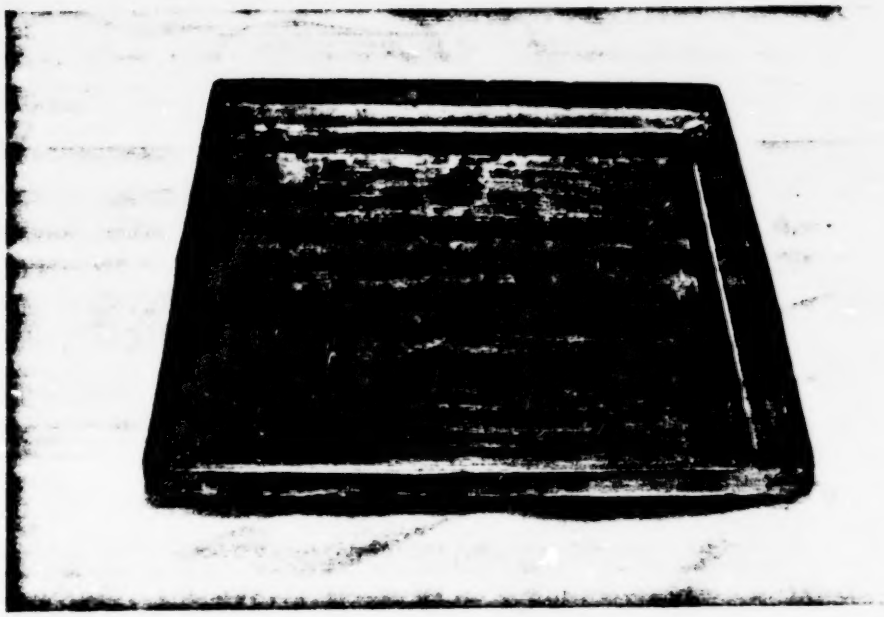

PHOTO 1: Aluminum tray

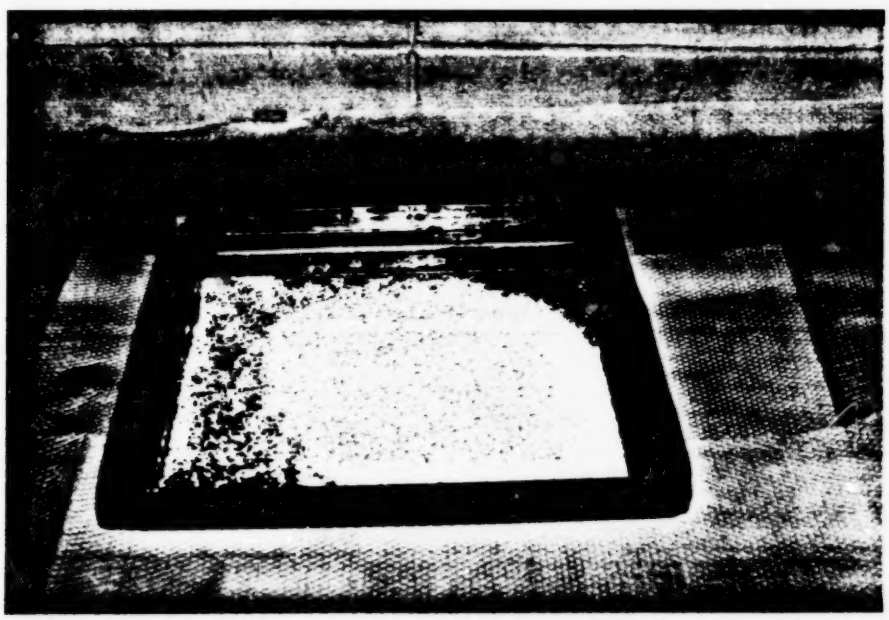

PHOTO 2: Aluminum tray and desiccant

PHOTO 3: Gypsum wallboard and template in place; paraffin wax being applied

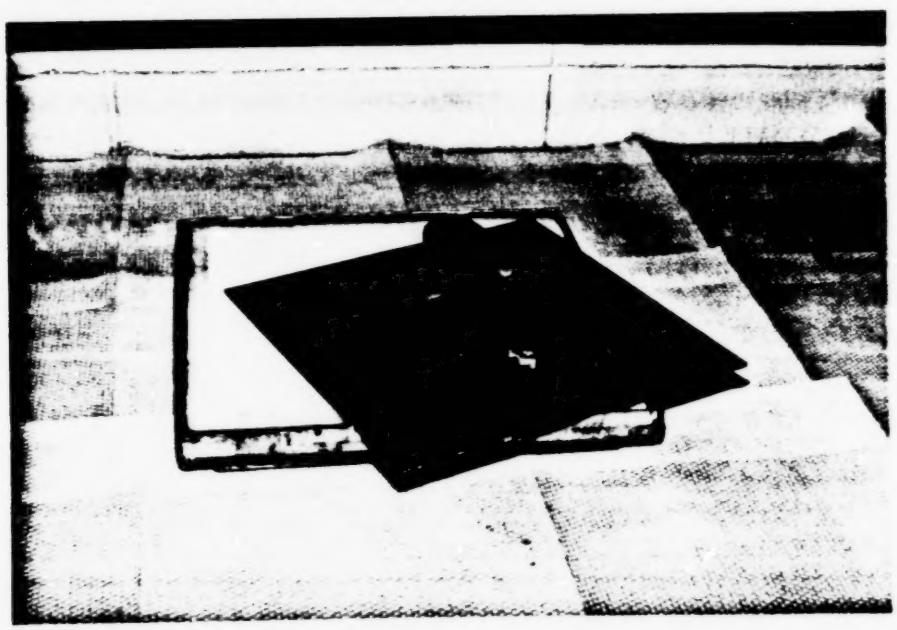

PHOTO 4: Template removed from assembly

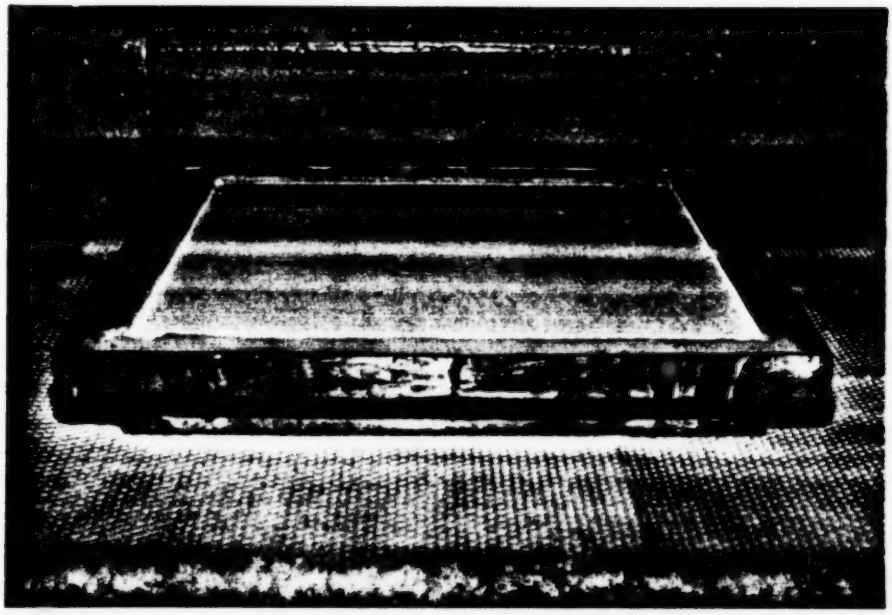

PHOTO 5: Completed assembly

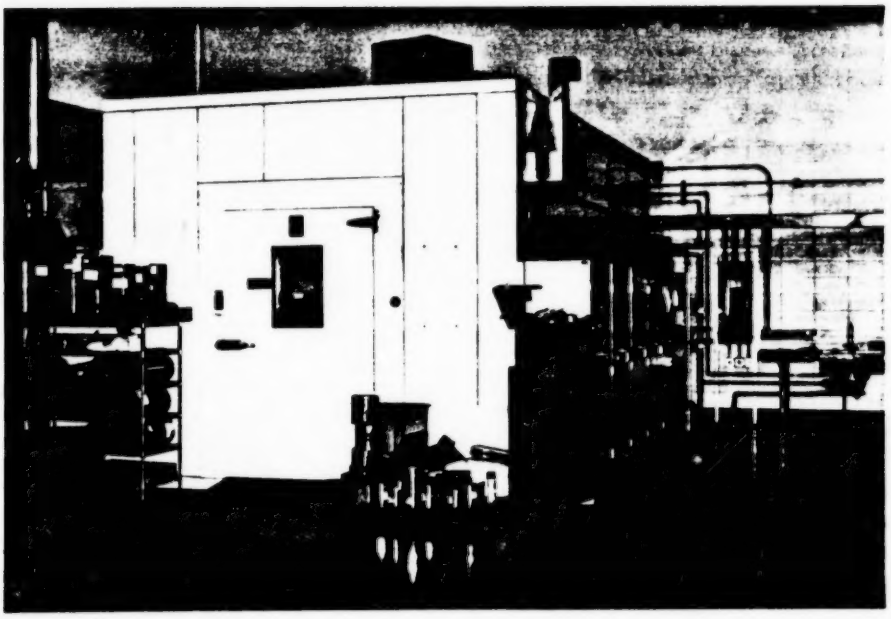

PHOTO 6: "Ambient Room"

PHOTO 7: Paint being applied during Commercial Application

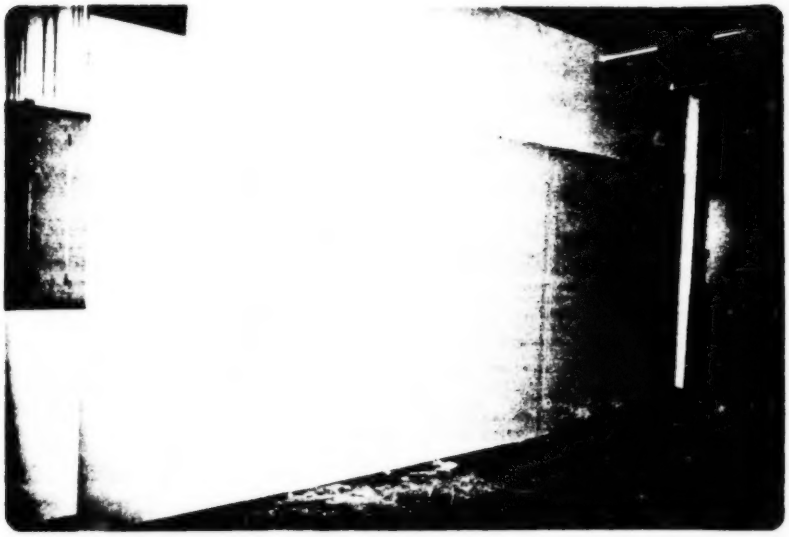

PHOTO 8: Completed wall for Commercial Application